California Air Resources Board

Quantification Methodology

California Department of Transportation
Low Carbon Transit Operations Program

California Climate Investments

Note:
The California Air Resources Board (CARB) is accepting public comments on the California Department of Transportation Draft Low Carbon Transit Operations Program (LCTOP) Benefits Calculator Tool and the Draft LCTOP Quantification Methodology until December 19, 2018 via GGRFProgram@arb.ca.gov. The Draft LCTOP Benefits Calculator Tool and Draft LCTOP Quantification Methodology are subject to change pending stakeholder comments and Final LCTOP Guidelines. The Final LCTOP Benefits Calculator Tool and Final LCTOP Quantification Methodology will be available on the California Climate Investments resources webpage at: http://www.arb.ca.gov/cci-resources.

CARB is also accepting public comments on the Draft Job Co-benefit Modeling Tool until January 4, 2018 via GGRFProgram@arb.ca.gov. The Final Job Co-benefit Modeling Tool will be included in the Final LCTOP Benefits Calculator Tool. The Draft Job Co-benefit Modeling Tool is available on the California Climate Investments resources webpage at: www.arb.ca.gov/cci-cobenefits.

DRAFT
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Section A. Introduction

California Climate Investments is a statewide initiative that puts billions of Cap-and-Trade dollars to work facilitating greenhouse gas (GHG) emission reductions; strengthening the economy; improving public health and the environment; and providing benefits to residents of disadvantaged communities, low-income communities, and low-income households, collectively referred to as "priority populations". Where applicable and to the extent feasible, California Climate Investments must maximize economic, environmental, and public health co-benefits to the State.

The California Air Resources Board (CARB) is responsible for providing guidance on estimating the GHG emission reductions and co-benefits from projects receiving monies from the Greenhouse Gas Reduction Fund (GGRF). This guidance includes quantification methodologies, co-benefit assessment methodologies, benefits calculator tools, and associated user guides. CARB develops these methodologies and tools based on the project types eligible for funding by each administering agency, as reflected in the program expenditure records available at: www.arb.ca.gov/cci-expenditurerecords.

For the California Department of Transportation (Caltrans) Low Carbon Transit Operations Program (LCTOP), CARB staff developed this LCTOP Quantification Methodology to provide guidance for estimating the GHG emission reductions and selected co-benefits of each proposed project type. This methodology uses calculations to estimate GHG emission reductions and avoided GHG emissions from transit operation and capital projects.

The LCTOP Benefits Calculator Tool automates methods described in this document, outlines documentation requirements, and provides a link to a step-by-step user guide with project examples. Projects will report the total project GHG emission reductions and co-benefits estimated using the LCTOP Benefits Calculator Tool as well as the total project GHG emission reductions per dollar of GGRF funds. The LCTOP Benefits Calculator Tool is available for download at: www.arb.ca.gov/cci-resources.

Using many of the same inputs required to estimate GHG emission reductions, the LCTOP Benefits Calculator Tool estimates the following selected co-benefits and key variables from LCTOP projects: reductions in criteria and toxic air pollutants (in tons), including diesel particulate matter (PM), nitrogen oxide (NOx), reactive organic gases (ROG), and fine PM less than 2.5 micrometers; passenger VMT reductions (in miles); fossil fuel use reductions; renewable energy generated (in kWh); fossil fuel energy use reductions (in kWh); travel cost savings ($); and energy and fuel cost savings ($). Key variables are project characteristics that contribute to a project's GHG emission reductions and signal an additional benefit (e.g., passenger VMT reductions, fossil fuel use reductions, renewable energy generation, and fossil-fuel-based energy use reductions). Additional co-benefits for which CARB assessment methodologies were not incorporated into the LCTOP Benefits Calculator Tool may also be applicable to the

project. Applicants should consult the LCTOP guidelines, solicitation materials, and agreements to ensure they are meeting LCTOP requirements.

Methodology Development

CARB and Caltrans developed this quantification methodology consistent with the guiding principles of California Climate Investments, including ensuring transparency and accountability.[1] CARB and Caltrans developed this LCTOP Quantification Methodology to be used to estimate the outcomes of proposed projects, inform project selection, and track results of funded projects. The implementing principles ensure that the methodology would:
- Apply at the project-level;
- Provide uniform methods to be applied statewide, and be accessible by all applicants;
- Use existing and proven tools and methods;
- Use project-level data, where available and appropriate; and
- Result in GHG emission reduction estimates that are conservative and supported by empirical literature.

CARB assessed peer-reviewed literature and tools and consulted with experts, as needed, to determine methods appropriate for the LCTOP project types. CARB also consulted with Caltrans to determine project-level inputs available. The methods were developed to provide estimates that are as accurate as possible with data readily available at the project level.

In addition, the University of California, Berkeley, in collaboration with CARB, developed assessment methodologies for a variety of co-benefits such as providing cost savings, lessening the impacts and effects of climate change, and strengthening community engagement. As they become available, co-benefit assessment methodologies are posted at: www.arb.ca.gov/cci-cobenefits.

Tools

The LCTOP Benefits Calculator Tool relies on methodology from the Congestion Mitigation and Air Quality (CMAQ) Program. The CMAQ Methods were developed by CARB and Caltrans, and are used statewide by transportation agencies to evaluate criteria pollutant emission reductions from transportation projects competing for State motor vehicle fee and federal CMAQ funding. The CMAQ Methods were used as the basis for developing the GHG emission reduction and air pollutant emission estimates from LCTOP project types. All of the equations and assumptions needed for this quantification methodology are included in this document and assumptions have been modified, as necessary. The CMAQ Methods document can be downloaded from: https://www.arb.ca.gov/planning/tsaq/eval/eval.htm.

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[1] California Air Resources Board. www.arb.ca.gov/cci-fundingguidelines

The CMAQ Methods are used statewide, subject to regular updates to incorporate new information, free of charge, and publicly available to anyone with internet access.

In addition to the CMAQ Methods, the LCTOP Benefits Calculator Tool relies on CARB-developed emission factors. CARB has established a single repository for emission factors used in CARB benefits calculator tools, referred to as the California Climate Investments Quantification Methodology Emission Factor Database (Database), available at: http://www.arb.ca.gov/cci-resources. The Database Documentation explains how emission factors used in CARB benefits calculator tools are developed and updated.

Applicants must use the LCTOP Benefits Calculator Tool to estimate the GHG emission reductions and co-benefits of the proposed project. The LCTOP Benefits Calculator Tool can be downloaded from: http://www.arb.ca.gov/cci-resources.
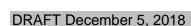
Updates

CARB staff periodically review each quantification methodology and benefits calculator tool to evaluate their effectiveness and update methodologies to make them more robust, user-friendly, and appropriate to the projects being quantified. CARB updated the LCTOP Quantification Methodology from the previous version[2] to enhance the analysis and provide additional clarity. The changes include:
- Updates to the GHG emission factors used in calculating emission reductions;
- Two new project types:
  - "Purchase replacement vehicle(s) and equipment/infrastructure in support of new expanded/enhanced transit service" for projects that fund vehicle replacement, and
  - "Purchase expansion zero-emission vehicle(s)" for projects that fund the purchase of additional zero-emission vehicles;
- Broadened eligibility of two project types:
  - "Purchase, construct, and/or install passenger amenities at transit stops/stations to encourage increased transit ridership" to "Purchase, construct, and/or install transit related amenities or infrastructure to encourage increased transit ridership" to incorporate infrastructure and other amenities that improve passenger experience, and
  - "Purchase, construct, and install new solar panels for transit facilities in support of new expanded/enhanced transit service" to "Purchase, construct, and install renewable energy/fuel for transit facilities in support of new expanded/enhanced transit service" to incorporate other sources of renewable energy and other renewable fuel types;
- Clarified eligibility of one project type:

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[2] Quantification Methodology for FY 2017-18. January 2, 2018.
https://www.arb.ca.gov/cc/capandtrade/auctionproceeds/caltrans_lctop_finalqm_17-18.pdf

- o "Purchase expansion zero-emission or low-emission vehicles and equipment in support of new expanded/enhanced transit service" to "Purchase expansion zero-emission vehicle(s) and equipment/infrastructure in support of new expanded/enhanced transit service";
- Quantification of emissions from vanpools as the VMT-weighted average of light-heavy-duty vehicle (LHD1) and medium-duty vehicle (MDV) vehicle classes; and
- Quantification of optional co-benefits for passengers' travel cost savings and transit agencies' energy and fuel cost savings.

Section B. Methods

The following section provides details on the methods supporting emission reductions in the LCTOP Benefits Calculator Tool.

Project Type

Caltrans developed 15 project types that meet the objectives of LCTOP and have methods to quantify GHG emission reductions.[3] Other project features may be eligible for funding under LCTOP; however, each project requesting GGRF funding must include at least one of the following:

- New expanded/enhanced transit service;
- Alternative transportation services;
- Purchase, construct, and/or install infrastructure to support zero-emission or low-emission vehicles in support of new expanded/enhanced transit service;
- Purchase, construct, and/or install equipment and facilities needed to provide expanded/enhanced transit service;
- Purchase expansion zero-emission vehicle(s);
- Purchase replacement zero-emission vehicle(s);
- Purchase, construct, and/or install infrastructure, equipment, or facilities to support zero-emission vehicle(s);
- Purchase expansion zero-emission vehicle(s) and equipment/infrastructure in support of new expanded/enhanced transit service;
- Purchase replacement vehicle(s) and equipment/infrastructure in support of new expanded/enhanced transit service;
- Purchase, construct, and install renewable energy/fuel for transit facilities in support of new expanded/enhanced transit service;
- Free or reduced fares;
- Network/fare integration;
- Purchase, construct, and/or install transit-related amenities or infrastructure to encourage increased transit ridership;
- Purchase and construct active transportation facilities that connect to stops/stations and encourage ridership; and
- Purchase and install equipment on transit vehicles to encourage increased transit ridership.

General Approach

Methods used in the LCTOP Benefits Calculator Tool for estimating the GHG emission reductions and air pollutant emission co-benefits by quantification method are provided

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[3] http://www.dot.ca.gov/drmt/splctop.html

in this section. The Database Documentation explains how emission factors used in CARB benefits calculator tools are developed and updated.

These methods account for emission reductions from displaced autos, transit vehicle emissions, and the use and generation of renewable energy. In general, the GHG emission reductions are estimated in the LCTOP Benefits Calculator Tool using the approaches in Table 1. The LCTOP Benefits Calculator Tool also estimates air pollutant emission co-benefits and key variables using many of the same inputs used to estimate GHG emission reductions.

Table 1. General Approach to Quantification by Method

New Service
Emission Reductions = Emission Reductions from Displaced Autos – Emissions from New Service
Increased Ridership
Emission Reductions = Emission Reductions from Displaced Autos
Fuel/Energy Reductions
Emission Reductions = Emission Reductions from Fuel/Energy Reductions
Technology Conversion
Emission Reductions = Emissions from Current Vehicle – Emissions from New Vehicle

Based upon the project type selected, one or a combination of the four quantification methods shown in Table 1 will automatically apply. The 15 project types fall into one of six possible combinations of quantification methods, including additional optional quantification methods available dependent upon the project type, as shown in Table 2.

Table 2. Project Types by Quantification Method

Project Type	Method
New expanded/enhanced transit service	New Service (Optional Technology Conversion and Fuel/Energy Reductions)
Alternative transportation services	
Purchase, construct, and/or install infrastructure to support zero-emission or low-emission vehicle(s) in support of new expanded/enhanced transit service	
Purchase, construct, and/or install equipment and facilities needed to provide expanded/enhanced transit service	
Purchase expansion zero-emission vehicle(s)	Technology Conversion
Purchase replacement zero-emission vehicle(s)	
Purchase construct, and/or install infrastructure, equipment, or facilities to support zero-emission vehicle(s)	Technology Conversion (Optional Fuel/Energy Reductions)
Purchase expansion zero-emission vehicle(s) and equipment/infrastructure in support of new expanded/enhanced transit service	New Service and Technology Conversion
Purchase replacement vehicle(s) and equipment/infrastructure in support of new expanded/enhanced transit service	
Purchase, construct, and install renewable energy/fuel for transit facilities in support of new expanded/enhanced transit service[4]	New Service and Fuel/Energy Reductions
Free or reduced fares	Increased Ridership (Optional Fuel/Energy Reductions)
Network/fare integration	
Purchase, construct, and/or install transit-related amenities or infrastructure to encourage increased transit ridership	
Purchase and construct active transportation facilities that connect to stops/stations and encourage ridership	
Purchase and install equipment on transit vehicles to encourage increased transit ridership	

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[4] For solar projects, use the National Renewable Energy Laboratory PVWatts Calculator to calculate the annual energy (kWh) expected to be generated from the solar panels. The energy generated will be entered into the LCTOP Calculator Tool as a Fuel/Energy Reduction with electric selected as the fuel type. The PVWatts tool can be accessed at: http://pvwatts.nrel.gov/.

A. Emission Reductions from New Service Project Types

Equation 1 is used to calculate both the GHG emission reductions and air pollutant emission reductions from New Service project types, estimated as the difference between the emission reductions from displaced autos and emissions associated with the operation of the new service. Equation 2 is used to calculate the emission reductions associated with auto VMT reductions. Equation 3 is used to calculate the annual VMT reductions from the proposed project. Equation 4 is used to calculate the emission estimates associated with the operation of the new service.

Equation 1: Emission Reduction Estimates from New Service

$$E = ER_{Displaced} - E_{New}$$

Where,   Units
E	=	Emission reduction estimates	$MTCO_2e$ or lbs
$ER_{Displaced}$	=	Emission reductions from displaced autos	$MTCO_2e$ or lbs
E_{New}	=	Emissions from new service	$MTCO_2e$ or lbs

Equation 2: Emission Reductions from Displaced Autos

$$ER_{Displaced} = \frac{AutoVMT \times AVEF}{CF}$$

Where,   Units
$ER_{Displaced}$	=	Emission reductions from displaced autos	$MTCO_2e$ or lbs
$AutoVMT$	=	Annual auto VMT reduced	miles
$AVEF$	=	Auto vehicle emission factor	grams/mile
CF	=	Conversion factor	grams/MT or grams/lb

Equation 3: Annual Auto VMT Reduced in Miles per Year

$$AutoVMT = R \times A \times L$$

Where,   Units
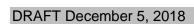|			
$AutoVMT$	=	Annual auto VMT reduced	miles
R	=	Annual increase in unlinked passenger trips directly associated with the proposed project	riders
A	=	Adjustment factor to account for transit dependency. Use documented, project-specific data or system average developed from recent, statistically-valid survey or default. Default: 0.5 for local service or 0.83 for long distance service, shuttle, and vanpools.	unitless
L	=	Estimated length of average unlinked passenger trip directly associated with the proposed project, calculated as passenger-miles divided by unlinked trips. Applicants may use data reported to National Transit Database for similar service.	mile(s) per rider

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Equation 4: Emissions from New Service

$$E_{New} = \frac{NSVMT \times NSEF}{CF}$$

Or (for train/ferry service use only)

$$E_{New} = \frac{NSFuel \times FuelEF}{CF}$$

Where,			Units
E_{New}	=	Emissions from New Service	MTCO$_2$e or lbs
NSVMT	=	The estimated annual VMT attributed to the operation of the new/expanded service	miles
NSEF	=	Emission factor based on service type	grams/mile
NSFuel	=	The estimated annual fuel attributed to the operation of the new/expanded service - only available for train and ferry services	unit of fuel
FuelEF	=	Emission factor based on fuel type, and engine tier for train	grams/unit of fuel
CF	=	Conversion factor	grams/MT or grams/lb

B. Emission Reductions from Increased Ridership Project Types

Equation 5 estimates the GHG emission reductions and air pollutant emission reductions from Increased Ridership project types as the emission reductions from displaced autos. Equation 6 is used to calculate the emission reductions associated with auto VMT reductions. Equation 7 is used to calculate the annual VMT reductions from the proposed project.

Equation 5: Emission Reduction Estimates from Increased Ridership

$$E = ER_{Displaced}$$

Where,   <u>Units</u>
E	=	Emission reduction estimates	$MTCO_2e$ or lbs
$ER_{Displaced}$	=	Emission reductions from displaced autos	$MTCO_2e$ or lbs

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Equation 6: Emission Reductions from Displaced Autos

$$ER_{Displaced} = \frac{AutoVMT \times AVEF}{CF}$$

Where,   <u>Units</u>
$ER_{Displaced}$	=	Emission reductions from displaced autos	$MTCO_2e$ or lbs
$AutoVMT$	=	Annual auto VMT reduced	miles
$AVEF$	=	Auto vehicle emission factor	grams/mile
CF	=	Conversion factor	grams/MT or grams/lb

Equation 7: Annual Auto VMT Reduced in Miles per Year

$$AutoVMT = R \times A \times L$$

Where,   <u>Units</u>
$AutoVMT$	=	Annual auto VMT reduced	miles
R	=	Annual increase in unlinked passenger trips directly associated with the proposed project	riders
A	=	Adjustment factor to account for transit dependency. Use documented, project-specific data or system average developed from recent, statistically-valid survey or default. Default: 0.5 for local service or 0.83 for long distance service, shuttle, and vanpools.	unitless
L	=	Estimated length of average unlinked passenger trip directly associated with the proposed project, calculated as passenger-miles divided by unlinked trips. Applicants may use data reported to National Transit Database for similar service.	mile(s) per rider

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C. Emission Reductions from Fuel/Energy Reduction Project Types

Equation 8 estimates both the GHG emission reductions and air pollutant emission reductions from Fuel/Energy Reduction project types as the amount of fuel/energy reductions the applicant will realize as a result of a proposed LCTOP project. Equation 9 is used to calculate the GHG emission reductions associated with fuel/energy reduction, while Equation 10 is used to calculate the air pollutant emission reductions associated with fuel/energy reduction.

Equation 8: Emission Reduction Estimates from Fuel/Energy Reduction

$$E = ER_{Fuel/Energy}$$

Where, <u>Units</u>

E	=	Emission reduction estimates	MTCO$_2$e or lbs
$ER_{Fuel/Energy}$	=	Emission reductions from fuel/energy reductions	MTCO$_2$e or lbs

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Equation 9: GHG Emission Reductions from Fuel/Energy Reduction

$$ER_{Fuel/Energy} = \frac{AnnualFuel \times FuelEF}{CF}$$

Where, <u>Units</u>

$ER_{Fuel/Energy}$	=	Emission reductions from fuel/energy reductions	MTCO$_2$e
$AnnualFuel$	=	The estimated annual fuel reductions to be realized as a result of the project	unit of fuel
$FuelEF$	=	Emission factor based on fuel type	grams/unit of fuel
CF	=	Conversion factor	grams/MT

Equation 10: Air Pollutant Emission Reductions from Fuel/Energy Reduction

$$ER_{Fuel/Energy} = \frac{AnnualFuel \times FuelCR \times FuelEF}{CF}$$

Where, <u>Units</u>

$ER_{Fuel/Energy}$	=	Emission reductions from fuel/energy reductions	lbs
$AnnualFuel$	=	The estimated annual fuel reductions to be realized as a result of the project	unit of fuel
$FuelCR$	=	Fuel consumption rate of the vehicle to realize fuel/energy reductions	miles/unit of fuel
$FuelEF$	=	Emission factor based on fuel type	grams/unit of fuel
CF	=	Conversion factor	grams/lb

D. Emission Reductions from Technology Conversion Project Types

Equation 11 estimates both the GHG emission reductions and air pollutant emission reductions from Technology Conversion project types, entailing the acquisition of cleaner vehicles (i.e., rolling-stock), calculated as the difference between the emissions associated with the current vehicle and emissions associated with the new vehicle. Equation 12 is used to calculate the emissions associated with the current vehicle and new vehicle.

For the acquisition of a new zero-emission vehicle, where there is no current vehicle to be replaced, applicants will enter current vehicle information of the newest available diesel-equivalent vehicle. For example, if the project was to purchase a zero-emission vehicle that will be operational in 2019, the applicant will input a 2019 model year diesel vehicle in place of the current vehicle information.

For the acquisition of a new vehicle(s), where there is a current vehicle(s) to be replaced, the LCTOP Calculator Tool requires project specific inputs regarding the current vehicle to calculate the emission estimates.

Equation 11: Emission Reduction Estimates from Technology Conversion

$$E = E_{CurrentVehicle} - E_{NewVehicle}$$

Where,   <u>Units</u>

E	=	Emission reduction estimates	$MTCO_2e$ or lbs
$E_{CurrentVehicle}$	=	Emissions from current/baseline vehicle	$MTCO_2e$ or lbs
$E_{NewVehicle}$	=	Emissions from new vehicle	$MTCO_2e$ or lbs

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Equation 12: Emissions from Current and New Vehicle

$$E_i = \frac{AnnualVMT \times VehicleEF_i}{CF}$$

Or (for train or ferry only)

$$E_i = \frac{AnnualFuel \times FuelEF_i}{CF}$$

Where,   <u>Units</u>

E	=	Emissions	$MTCO_2e$ or lbs
VehicleEF	=	Emission factor based on project-specific inputs	grams/mile
AnnualVMT	=	The estimated annual VMT of the vehicle to be acquired	mile
AnnualFuel	=	The estimated annual fuel of the vehicle to be acquired, only available for train and ferry services	unit of fuel
FuelEF	=	Emission factor based on fuel type, and engine tier for train	grams/unit of fuel
CF	=	Conversion factor	grams/MT or grams/lb
i	=	Current or new vehicle	

Section C. References

The following references were used in the development of this Quantification Methodology and the LCTOP Benefits Calculator Tool.

California Air Resources Board. (2018). California Climate Investments Quantification Methodology Emission Factor Database. http://www.arb.ca.gov/cci-resources

California Air Resources Board. (2018). CA-GREET 3.0. https://www.arb.ca.gov/fuels/lcfs/ca-greet/ca-greet.htm

California Air Resources Board, California Department of Transportation. (2005). Methods to Find the Cost-Effectiveness of Funding Air Quality Projects for Evaluating Motor Vehicle Registration Fee Projects and Congestion Mitigation and Air Quality Improvement Projects. https://www.arb.ca.gov/planning/tsaq/eval/eval.htm